

5 Session 3: Building Energy Assessment Methodologies and Practices

**Assessment of Industrial Energy Systems: A Well-defined Methodology
Is the Key to Success and to Investment Decisions**

Presenter: Dr. Curt Björk. Energy @ Optimum (Sweden).

Assessment of Industrial Energy Systems

**The methodology as a key to
success**

**By
Dr. Curt Björk
Curt Björk Fastighet & Konsult AB
Sweden**

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- The Key questions are:
 - Why do you use energy?
 - What do you want to accomplish with it?
 - Are there alternative ways of accomplishing your goals?
 - Which are your motives for wanting a change?
 - Who supports you and how?

Check List, part 1

Energy use

Statistics from the utility or/and your own meters or bills
Contracts
Sub metering, distribution of costs (behaviour goes with responsibility)
Key figures
Benchmarking

Production or activity

Description of processes and activities
Equipment, machines, rated power
Excess heat from equipment
Heat recovery, heat sources and heat sinks
Production hours
Operation time for processes
Already performed energy efficiency improvements?
Development of production in the near and long term future

Building

Layouts, drawings
Area, volume, number of floors
U values for roof, walls, windows, doors,
Status regarding air leakage, infiltration
Outdoor sun protection, solar films, number of glasses in the window

Heating system and heat supply

Heat distribution

Pumps, regulators, valves,

Cooling systems

Cooling units, regulation, settings, operation strategies

Use of cooling from the outdoor air

Flows, pump operation, ΔT

Ventilation system

Purpose of ventilation?

Fan power, flows, operating hours per day and system

Which part of the building does the system serve?

Heat recovery, heat exchangers, settings regarding temperature level

General ventilation vs process ventilation, pressure balance in building

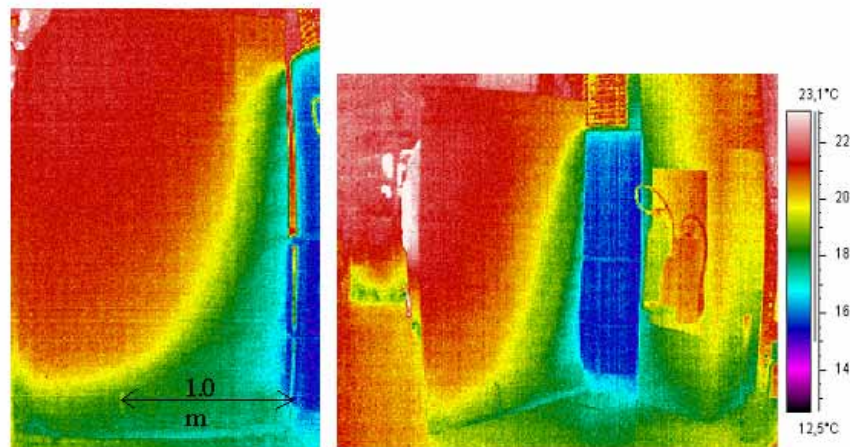
Compressed air systems**Lighting**

- Define
- Measure
- Analyse
- Implement
- Control

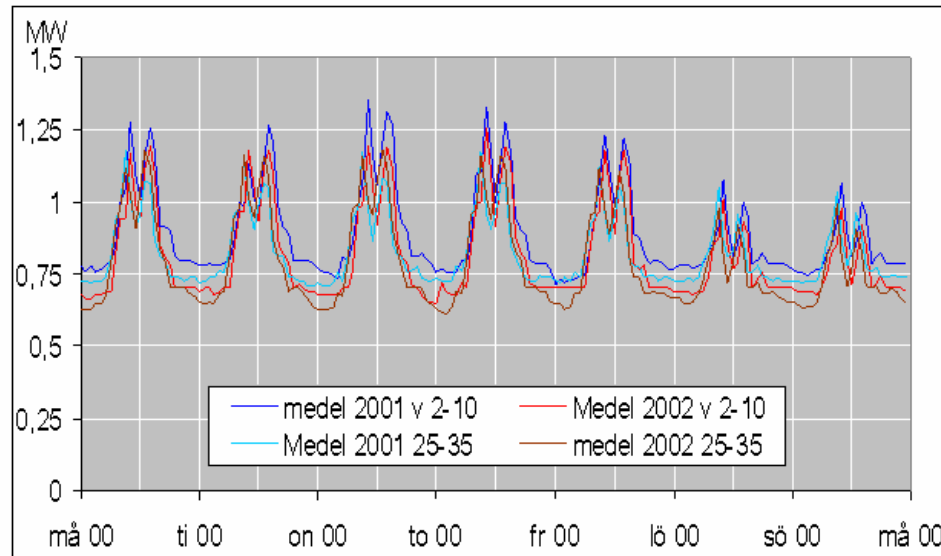
Six Sigma

• Methodology for ventilation

- Evaluate your motives, purpose of ventilation
- Analyse system behaviour and status
- Air balance, supply and exhaust air (general and process ventilation in balance)
- Reduction of general ventilation by at least 50 % during the cold season
- Flexible systems, VSD, modern control technology
- Use the nature's gifts, e.g. night time cooling by ventilation system
- Refine your solutions



Example, measurements, steam load



The analysis phase

- Review of existing systems (with your experience in the back of your head and with self confidence)
- Measurements regarding important parameters
- Interviews with people on the floor
- Night time walkabout
- Energy efficiency measures (no limitations)
- Calculations, analysis tools
- Preliminary plan, written report
- Investment decisions
- Action plan, fine-tuned and revised

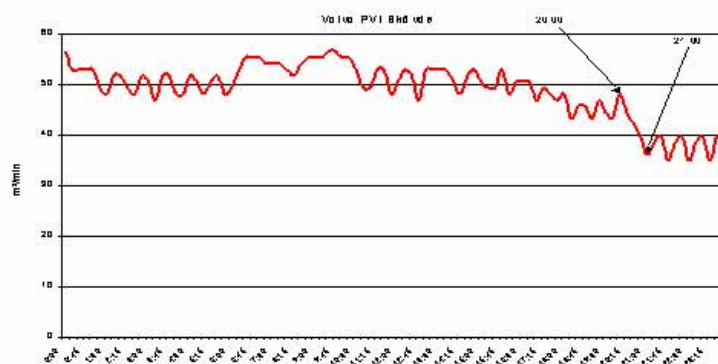
What can you expect to find?

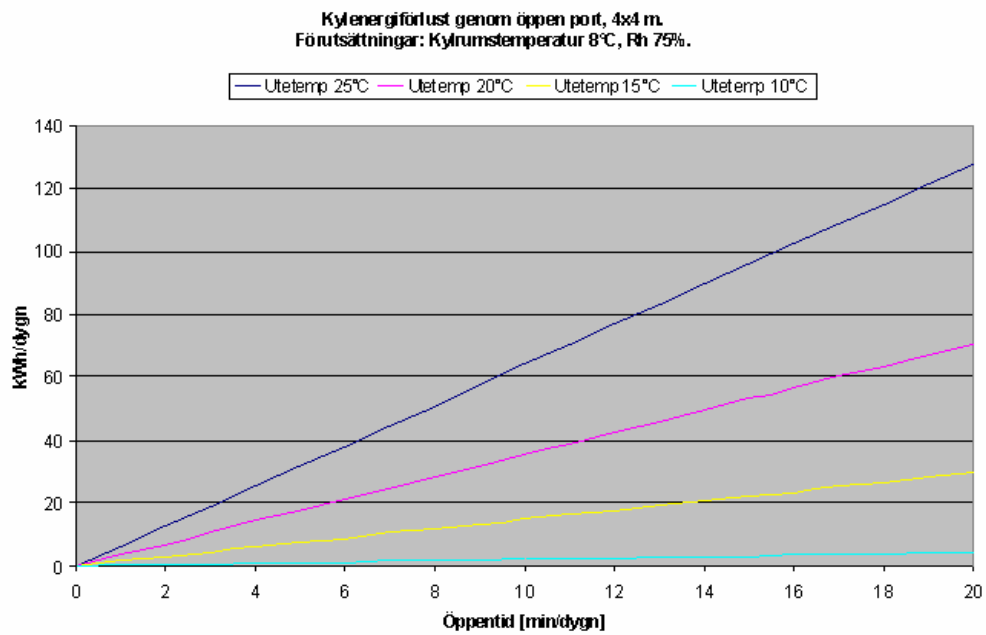
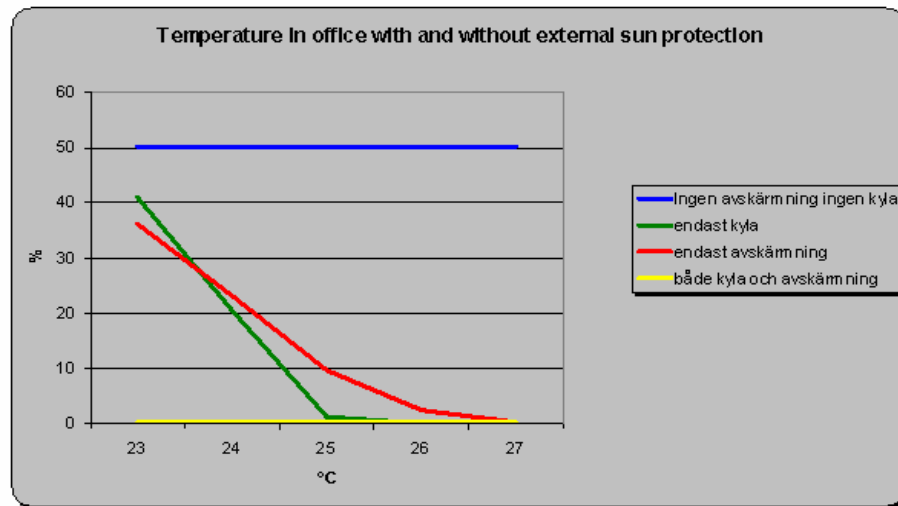
- Be calm, we haven't seen all yet !

1. The timer that seemed to be wrong by 12 hours. That was the case but it also only had the possibility to turn equipment (large ventilation units) on, never off. This meant 8760 hrs/year.
2. The ground heating system that tried to heat the Swedish ground to + 20 °C. The staff thought that the thermostat setting was for an aerotemper.
3. The compressed air duct that went under the concrete foundation / floor in a factory and ended there, with an open end. It was discovered when the durability of the floor was checked. 5 m³/min for 10 years cost a lot of money. One year earlier the company bought a new compressor since they were short of capacity. ...

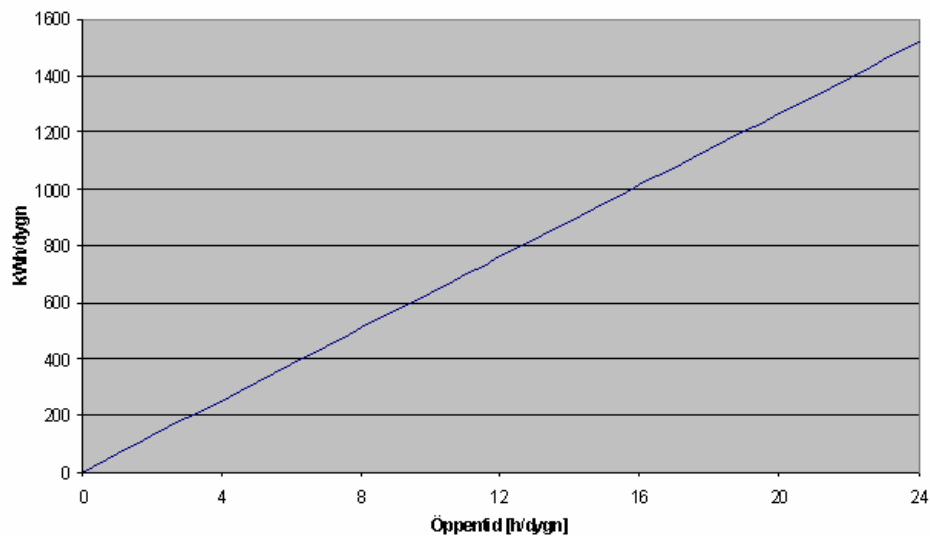


Åtgärdsförslag – Tryckluft palett-tvätten

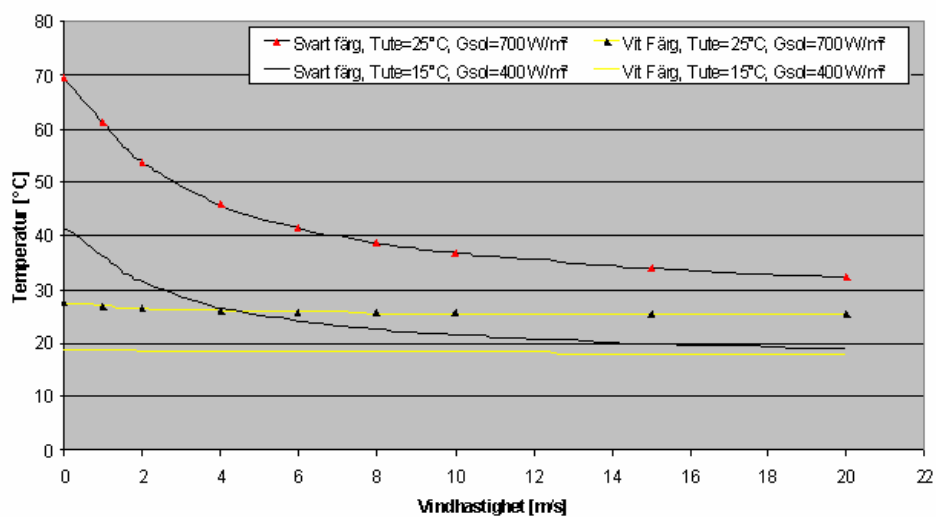


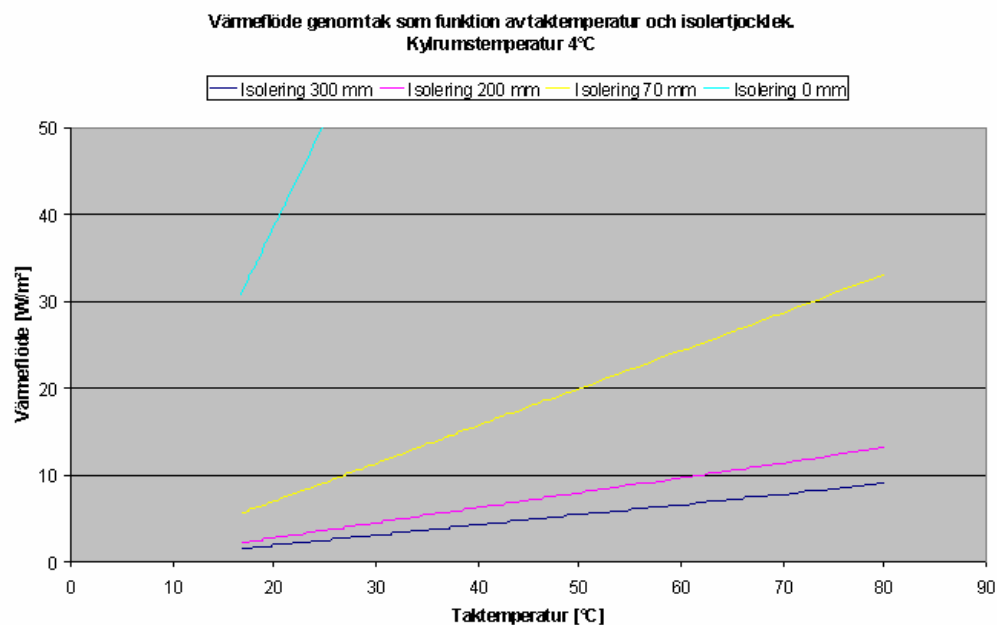


Kylenergiförluster genom öppen port, 4x4 m.
Förutsättningar: Mellan kylrum 4°C, och yttre lokal, 10°C, Rh 75%.



Taktemperatur som funktion av vindhastighet och färg





Reduce your energy costs- Advice for industries and owners of commercial buildings

Highest priority on electricity use – it won't become less expensive

Adjust the operation time for your help systems to the actual operating hours

Adjust your regulators and controllers. Heating and cooling vs outdoor temperature

Stop heating distribution pumps in the spring and the cooling distribution pumps at autumn.
Don't pump if you don't have to.

Avoid simultaneous heating and cooling

Review settings and curves in the building control systems.

No cooling should be allowed in buildings without external sun protection

Cooling of buildings should be in terms of how many degrees below outdoor temperature

Every possibility to use cooling by nature should be used / Free cooling won't cost you a fortune

Perform night time (Weekend) walkabouts. Measure and analyse energy use during non-production hours

Connect the aerotempers to the operation of doors and gates / locks

Avoid compressed air. There are always alternatives available !! Seal leakages, turn off unnecessary users, decentralize, reduce pressure, control efficiently.

Do not heat supply air more than necessary. Internal loads create higher-than-desired temperature.

VSD on ventilation fans will give you the tool to optimize the ventilation flow. Dimensioning case is probably the summer case. Reduced flow increases relative humidity and saves energy.

LCC as a tool will help you to get more efficient lighting.

Actual savings in a selection of projects

Company	Facility	El. use (MWh)	*Savings (MWh)	Heating (MWh)	*Savings (MWh)	*Savings Totally (%)
Posten	Segeltorp Paketterminal	1200	280	900	300	28 %
Posten	Sundsvall Brevterminal	2300	590	800	250	27 %
Arvid Svensson Fastigheter	Vallby-Institutet	2110	750	3715	1000	30 %
Botkyrka kommun	Tumba sjukhem	2300	250	5000	1515	25 %
Täby kommun-fastigheter Pågående	Skolor i Täby kyrkby			1854		
EBÖ	Gjuteri, Eskilstuna	6800	620	1311 + 2300 tons LPG Water 110 000 m3	1170 - 60 000 - 80 000	22 % 55 %
Volvo Personvagnar	Skövde Motorfabrik	61 000	26 800	24 600	9 100	36 %**
Skanska FM	DNE X-tryckeriet Åkalla	25 000	3 300	7 300	2 400	18 %
Totalt		120 700	34 600	43 600	15 800	31 %

*Savings with pay-off < 2 years

Dr. Curt Björk

- Curt Björk Fastighet & Konsult AB
 - Tallkullegratan 21
 - SE-590 72 Ljungsbro
 - Sweden
- +46 13 661 21
- +46 739 50 48 07
- curt.bjork@telia.com

ESL. Continuous Commissioning: An Effective Method for Energy Reductions

Presenter: Dr. Charles Culp. Texas A&M University,

Achieving Energy Efficiency in HVAC

US Army
CERL Meeting

Charles Culp, Ph.D., P.E.
W. Dan Turner, Ph.D., P.E.
Jeff Haberl, Ph.D., P.E.
David Claridge, Ph.D., P.E.
Energy Systems Laboratory
Texas A&M University System

October 7th, 2003
Chicago



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Energy Growth Continuous Commissioning[®] CC Examples



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Efficiency Is Critical To US Energy Security

World Population Growth Is High
World Consumption Will Increase
Competition for Energy Will Increase

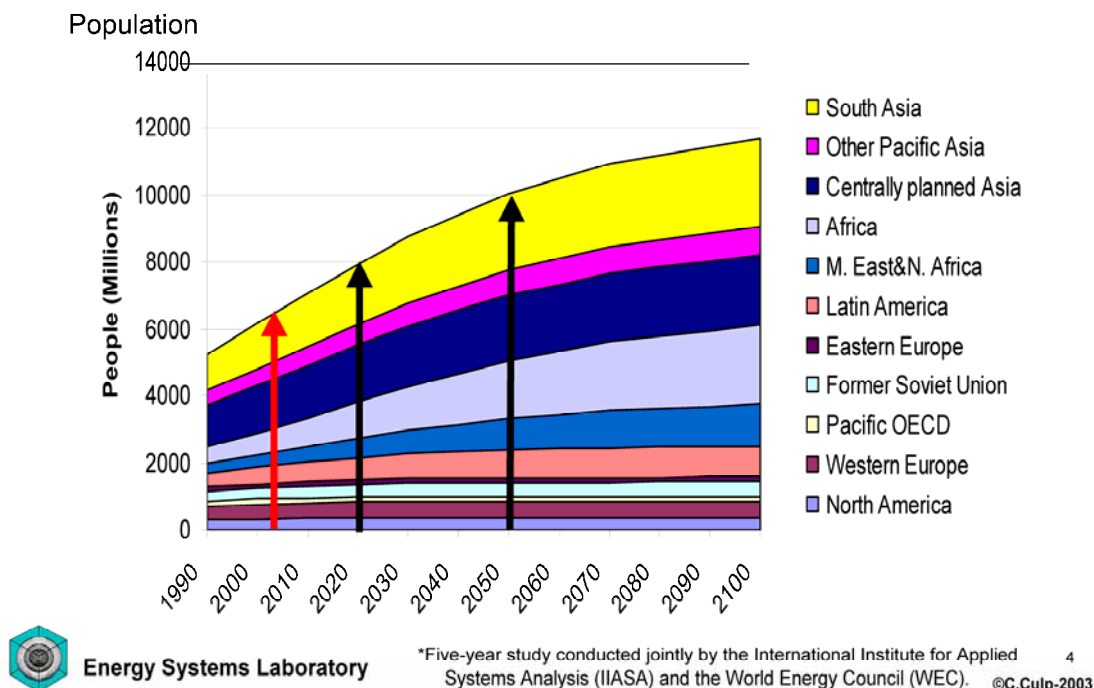


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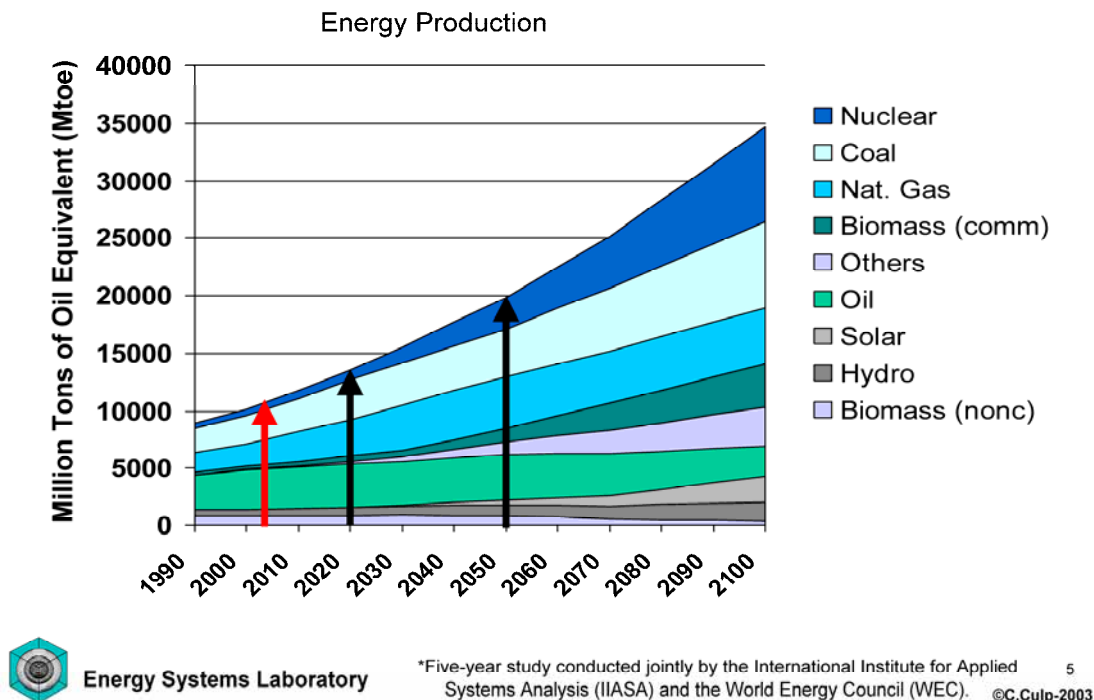
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World Population



World Energy Use



Continuous Commissioning

- CC Reduces Energy Use
 - Increases comfort
 - Typically 10% to 40%. Average is ~ 20%
- CC Cost Structure
 - CC costs range from \$0.25 to \$0.80 per sq.ft.
 - Costs vary based on complexity and the improvements being done
 - Payback is usually under 3 years and often under 2 years



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CC Evolution

- LoanSTAR – Loans to Save Taxes and Resources (approved in 1988)
- \$98.6 Million Capital Retrofit Fund for Energy Efficiency Improvements
- DOE Demonstration Project (retrofits had to be metered and monitored for verification of energy savings)
- Texas A&M's Energy Systems Lab was selected as the M&V subcontractor



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CC Evolution

- Hourly data (electrical, NG, chilled water, steam, hot water, and some submetering) were coming into Energy Systems Lab
- Developed analysis methodologies to determine savings – IPMVP and ASHRAE 14P
- Had hourly data on hundreds of LoanSTAR buildings—Large, building energy consumption relational database



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CC Evolution

- Began analyzing the hourly data for operational improvements, i.e., systems which could have improved operation schedules or be shut off completely
- Called these O&M improvements (~1992)
- In 1993, we began the development of air-side models to analyze performance
- Started going into buildings to make operational improvements
- Commissioned the retrofitted buildings in LoanSTAR and made additional operational improvements
- Additional savings averaging 20% of utility bills were achieved (over and above the retrofit savings!)



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CC Evolution

- Being introduced and accepted by ESCOs
- ESL is currently working with 2 ESCOs to incorporate CC into their offerings
- Major Benefits to ESCOs
 - High payback results in additional opportunities to build infrastructure
 - High savings and payback when major equipment does not need replacing
 - Method to find additional savings if savings shortfall exists

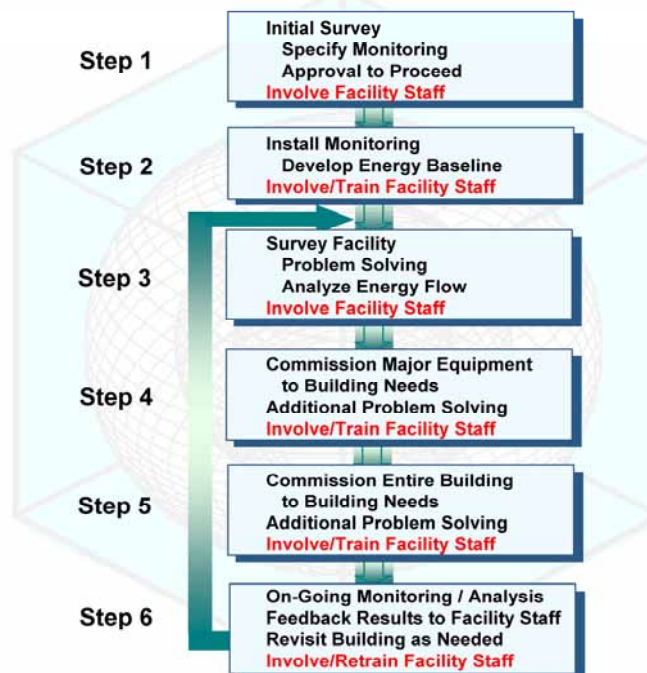


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Continuous Commissioning



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Continuous Commissioning

- Texas Capitol Extension:
 - Built in 1992 and was commissioned to design specifications.
 - CC process reduced heating and cooling by 30%
 - Payback of less than 1 year.
- Zachry Engineering Center (Texas A&M University):
 - Classroom/laboratory/office building (324,000 sq.ft.) received a VAV retrofit and EMCS upgrade in 1991.
 - CC reduced heating and cooling consumption by 50%.
- Brooke Army Medical Center:
 - 1.2 million sq.ft. facility built in the mid-90s with an EMCS.
 - CC process reduced cost 10% in 1998-99
 - Payback was 1.1 years
- Fairview Medical Center – Unit J:
 - Acute Care Facility (600,000 sq.ft.) built in 1981-82.
 - CC reduced heating and cooling cost by about 25%
 - Payback of 1.9 years.



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CC Examples

1. Terrell State Hospital (commissioned older, retrofitted facility)
2. State of Utah – Matheson Courthouse (fairly new, modern building)
3. Prairie View A&M University (includes CC as an ECM in a retrofit project)



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Terrell State Hospital

- Building: 20 major buildings with a total floor area of 676,000 square feet
- Chiller system: 5 chiller plants connected to a 7000 ton-hr thermal storage system
- AHUs: 80
- Modern Control System



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Terrell State Hospital

- Old facility
- Operating staff is short of manpower
- Comfort problems exist in most of the buildings
- Thermal storage system operation was unstable
- Any modifications are subjected to pre-approval by operating staff



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Terrell State Hospital

- Retrofit Implemented – Cool Storage
 - Achieved only 55% of savings projected by design engineer
 - Thermal storage system had to turn on a chiller during utility peak period
 - Client could not repay loan from utility savings
 - SECO asked ESL to investigate for possible commissioning opportunity



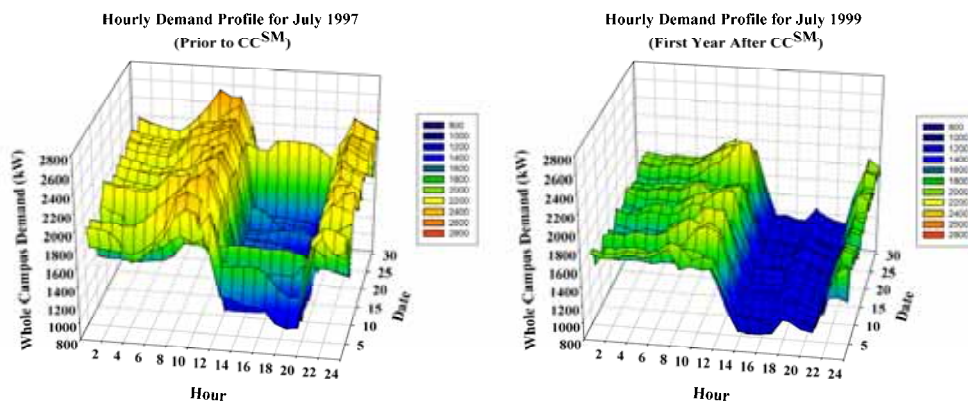
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Terrell State Hospital

- Retrofit Implemented – Cool Storage



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Terrell State Hospital

- Results
 - Brought savings to 95% level in 1st year
 - Optimized control systems operation
 - Optimized chilled water tank charging and operation
 - Calibrated sensors and identified hardware problems, both for maintenance staff and controls vendor to fix
 - Achieved additional savings in 2nd year of CC to bring total savings to about 105% of audit-estimated savings



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Terrell State Hospital

- Results
- First year savings after CC \$175,112
 - \$34,096 for Demand
 - \$88,832 for Electricity
 - \$55,736 for Gas
- Utility Costs
 - Demand costs: \$7.63/kW-Mo
 - Energy costs: \$0.037/kWh
 - Gas costs: \$2.40/MMBtu
- Measured savings: \$175,000/yr in first year



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Building Description

- Matheson Courts Complex
- COVERED AREA : 420,000 ft²
- CONDITIONED AREA: 370,000 ft²
- 37 courtrooms, offices, holding cells, 3 level underground parking



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Matheson Courthouse

Energy Information

- 2001 utility bills were \$400,000 (\$300,000 for electricity, \$100,000 for gas)
- Energy Cost Index = \$1.08 per square foot per year, based on conditioned area

Installed HVAC Equipment

- One (1) 400-ton and one (1) 770-ton chiller
- Six (6) single duct, VAV AHUs, with hot water terminal reheat
- Two (2) 500-hp hot water boilers
- Modern DDC building automation system



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CC Findings

- Numerous bad sensors
- About 70% of the VAV boxes were in need of recalibration or broken
- Two boilers operating continuously on high fire
- Two pumps operating when one pump needed
- Glycol de-icing system dysfunctional
- Building start-up/shut-down sequence was not optimal
- A few maintenance problems were identified



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CC Findings

- Outside air temperature sensor was not reading correctly and RH sensor was giving false outputs
- Chiller sequence was not optional
- Duct and building static pressure sensors were out of calibration
- Insulation was missing around one of the AHUs, which allowed outside air to mix with building return air
- Exhaust air dampers would not close completely or sometimes failed to open



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CC Actions

- Replaced / recalibrated numerous sensors
- Recalibrated all 500 plus VAV boxes
- On boilers, changed to one boiler operation, starting on low or medium fire
- Revised two-pump operation to one-pump operation on systems
- Fixed glycol loop operation
- A “semi-occupied” mode was created to optimize building start-up



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CC Actions

- Chiller start-up sequence in spring allowed all chillers, cooling towers, pumps to run, which created an electrical demand spike and start-up sequence was modified
- Reprogrammed logic that allowed both chillers to run during changeover from small to large chiller
- Dampers were adjusted to close as completely as possible
- Two (2) leaking valves were repaired
- Insulation was added to one (1) AHU to seal off outside air
- Sticking isolation valve on small chiller was repaired



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CC Actions

- Exhaust dampers were adjusted and programming logic was changed to ensure dampers were closed when exhaust fans were off
- A cold deck temperature reset schedule was implemented for each AHU, based on outside air temperature
- Hot water temperature was lowered to 155-160°F (the lowest temperature the boiler controller could go). A recommendation was made to purchase a new controller which could be programmed to have a reset schedule with OAT



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Results of Continuous Commissioning

- Model savings (2001 prices, weather normalized)
 - \$80,000 annual savings (60% gas, 40% electricity)
- Actual Savings for 2002
 - \$116,000 (both gas and electricity were somewhat cheaper than baseline prices)
- Actual ECI
 - 2002 ECI fell to \$0.77 per square foot/year
 - 2001 ECI was \$1.08 per square foot/year
- Simple payback was 1.2 years
- Over 700 operating hours were eliminated
- **Energy office expanding initiative statewide with a team of Utah staff, private industry, and the ESL**



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Prairie View A&M University

Continuous Commissioning in a Capital Retrofit Project



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Prairie View A&M - PVAM

Project Development

- Investment grade audit performed for capital retrofits
- ESL concurrently conducted CC audits
- Original intent was a \$5 million loan
- When savings and ECMs were identified, project simple payback was under 8 years
- With a lower payback, customer wanted to get two new chillers and we were asked to revise project to include additional chillers and stay within a 10-year payback required by LoanSTAR
- Final project involved two loans totaling \$4.7M and \$1.7M each, with a combined payback of 9.4 years



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Prairie View A&M - ECMs

ECM	Simple Payback, yrs
Lighting retrofits	6.0
Replace two chillers	19.8
Repair steam system	7.2
Install motion sensors	7.3
Expand chilled water loop	8.4
Convert to primary/ secondary pumping	9.0
Replace DX systems	13.0
Upgrade DDC EMCS	13.7
Continuous Commissioning	3.0

Project Cost = \$6,436,460

Simple Payback = 9.4 years



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Prairie View A&M - PVAM

CC Measures

- Hot and cold deck temperature resets
- Elimination of unnecessary simultaneous heating and cooling
- Air and water optimization
- Duct static pressure resets
- Sensor calibration/repair
- Improved start/stop/warm-up/shutdown schedules
- Improved chiller and boiler plant operation
- Retrofit commissioning



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Prairie View A&M - PVAM

CC Summary

- CC represents roughly 1/3 of project savings
- Payback = 3 years
 - While CC savings results vary from building to building, overall average savings are 15-25%
 - Using CC as an ECM in an energy conservation project allows longer payback items to be purchased

The CC process has been successfully applied

- To existing buildings after energy retrofits
- To existing buildings with no retrofits
- To new buildings
- As an ECM in major energy retrofit projects



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Continuous Commissioning

Savings & Costs

Buildings	Savings (\$/kft ² /yr)	Costs (hr/kft ²)
Hospitals	\$430	4.74
Lab/Offices	\$1,260	3.68
Class/Offices	\$430	2.26
Offices	\$220	3.29
Schools	\$170	3.36
Average	\$540	3.59



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Continuous Commissioning

Performance

- Over 165 buildings commissioned since 1993
- Cumulative measured savings through August 2002 – about \$74 million
 - LoanSTAR - \$40 million
 - Texas A&M - \$24 million
 - Others - \$10 million
- **CC makes sense**



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Summary

- Energy efficiency can make a valuable contribution to US energy security
- Continuous Commissioning improves comfort
- Commissioning improves efficiency with excellent payback
- Measurement and Verification needed to sustain savings



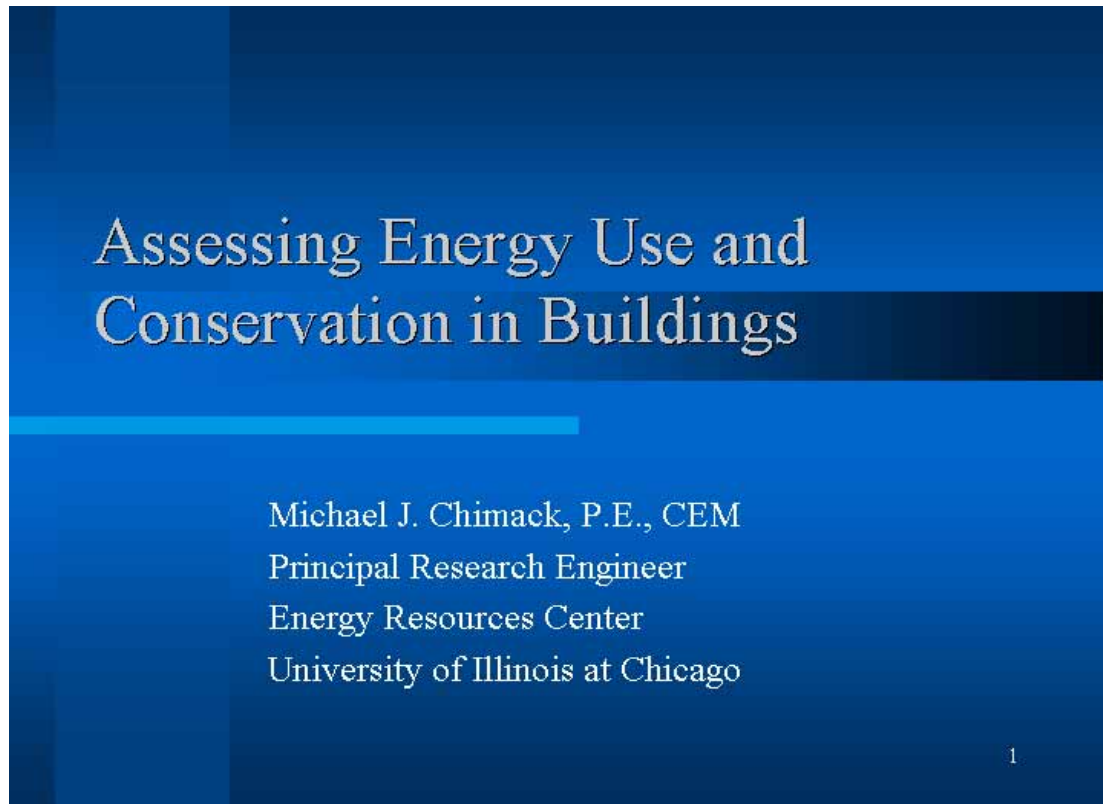
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Assessing Energy Use and Conservation in Commercial and Institutional Buildings

Presenter: Mr. Michael Chimack. University of Illinois in Chicago, ERC.



Need for Energy Management

- **Three Major Issues**

- **Economic Competitiveness**
 - Reduce commercial/institutional energy use
 - Reduce production costs and industrial energy use
- **Energy Security**
 - Reduce oil imports
 - Reduce vulnerability to oil embargo
- **Environmental Quality**
 - Issues of global warming, acid rain, ozone depletion

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Statistics

- **US Energy Consumption (EIA Annual Energy Review-1998)**

- | | |
|---------------------------------|------------|
| – Industrial | 35% |
| – Commercial/Residential | 34% |
| – Transportation | 27% |

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Commercial Consumption

- **Electric End-Use (1995-EIA)**

- 2,608 trillion Btu total
- **Lighting** **46%**
- **Space Cooling** **20%**
- **Ventilation** **6%**
- **Space Heating** **4%**
- **Water Heating** **2%**
- **Other** **22%**

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Commercial Consumption

- **Natural Gas End-Use (1995-EIA)**

- 1,946 trillion Btu total
- **Space Heating** **56%**
- **Water Heating** **27%**
- **Cooking** **10%**
- **Other** **7%**

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Assessment Overview

- **Energy Audit Goals**

- Identify the types and costs of energy used
- Identify opportunities that reduce energy use (energy costs)
- Conduct economic analyses on opportunities to determine cost effectiveness (ROI, ROR)
- Recommend implementation strategy
- Recommend implementation financing

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Energy Savings Opportunities

- **No-cost and maintenance issues**
 - 2 to 6 percent expected savings
- **Low-cost/short payback actions**
 - 6 to 15 percent expected savings
- **High-cost/longer payback actions**
 - 15 to 30 percent savings

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Energy Auditing 101-Baseline Assessments

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Top 5 Requirements for Success

- Management commitment to EM
- Staff cooperation
- Management willing to invest in energy projects
- Time and budget available to conduct energy assessments
- Implementation strategies

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Energy Auditing

- **Initial Data Gathering**

- **Energy bills**
- **Systems inventory**
- **Facility specifications**
- **Interviews with managers/operating engineers**
 - **Facility operating hours**
- **Other**
 - **Weather data (computer simulation)**

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Energy Auditing

- **Energy Bill Analysis**

- **First step**
- **Shows the proportionate use of different energy sources as compared to the total energy cost**
- **Demonstrates potential areas where energy is being wasted**
- **Puts upper limit on what can be saved**

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Energy Auditing

- **Systems Inventory**
 - The more extensive the inventory, the more accurate the understanding of energy use
 - Submetering opportunities
- **Facility specifications**
 - Original construction specs on building
 - Provides benchmark for energy use

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Energy Auditing

- **Interviews with managers/operating engineers**
 - Age/ “ility” issues with existing equipment
 - Their “wish list”
 - Facility operating hours
 - Equipment operating hours

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Building/System Retrocommissioning

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Commissioning-What is it?

- The process of ensuring that systems are designed, installed, functionally tested and capable of being operated and maintained to perform in conformity with the design intent.
– (ASHRAE Guideline 1-1996)

Retrocommissioning-Why?

- **Retrocommissioning**
 - Applies commissioning principles to existing buildings that were never commissioned
- **Why?**
 - Age of building/equipment
 - Improper/inadequate design from start
 - Cookbook engineering (design)
 - Suppliers delivered “or equivalent” products
 - Owners lack of involvement
 - Build them faster and cheaper

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Retrocommissioning

- **Focuses on energy-using systems**
 - (e.g. mechanical, lighting, controls)
- **Ensures system functionality**
 - Optimize how equipment and system operates
 - Optimize how systems function together
 - Energy use is usually reduced

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Retrocommissioning Benefits

- **Provides energy cost savings that often payback investment**
- **Reduce maintenance costs, reduce premature equipment failure**
- **Identifies system operating, control, and maintenance problems**
- **Aids in long-term planning and major maintenance budgeting**

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Retrocommissioning Benefits

- **Asset management activity**
 - Increases ability of O&M department to provide quality services
- **Risk-reduction method**
 - Reduce risk of tenant loss, early equipment failure, IAQ and high utility bills

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Retrocommissioning Benefits

- **Internal benchmarking technique**
 - Set internal benchmarks for building operating performance
- **Part of energy management program**
 - Supports the efficient operation of energy using equipment
- **Provides operators with training**

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Retrocommissioning Costs

- **Costs dependant on:**
 - Building type and size
 - Age and condition of building
 - Status of equipment installed
- **Commissioning Costs:**
 - Range from \$0.03-\$0.43 per square foot
 - Average \$0.08-\$0.20 per square foot
- **Energy Cost Savings**
 - Average savings of 5-30% of total utility cost
 - Less than 3 year payback periods, often less than 1 year
- **0.7 quads potential savings by US Building Stock due to Retrocommissioning alone**

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RetroCx-Where, When, How

- **Applicable over all markets**
 - Predominantly commercial/institutional
- **Successful only when clients are very aggressive about energy management**
- **Can be completed anytime**

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Successful Projects

- **Projects with greatest potential have:**
 - Management support
 - Motivated and available building staff
 - High EUI (\$/sq.ft./yr.)
 - Easily accessible building documentation
 - Digital control systems

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Conducting an Energy Assessment

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Electricity Bill

- **Bundled Rates**
 - Fixed cost for demand and use
- **Unbundled Rates (deregulation)**
 - **Cost Components**
 - Customer Cost-constant
 - Demand Cost (kW)-power being used
 - Usage Cost (kWh)-energy being used
 - Fuel Adjustment/Taxes
 - PF/Ratchet clauses (if applicable)

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Natural Gas Bill

- **Customer Cost-constant**
- **No Demand Cost**
- **Usage Cost**
 - Gas being used
 - Firm delivery
 - Interruptible delivery
- **Taxes etc.**

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Conducting an Audit

- **Lighting**
 - type of lighting
 - number of fixtures, lamps, ballasts (wattage)
 - controls/operating hours
- **Building Envelope**
 - roof, wall, floor and window areas and conditions
 - insulation levels
 - pressurization

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Conducting an Audit

- **Space Cooling-HVAC**
 - number of units/coil conditions
 - pumping energy
 - air filtration
 - controls/operating hours
- **Space Heating-HVAC**
- **Boiler/Steam Distribution**
 - combustion analysis
 - insulation, leaks, traps, condensate

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Conducting an Audit

- **Hot Water Distribution System**
 - condition of equipment/operating schedules
- **Motors**
 - type, size, efficiency, %load
 - VFD evaluation
- **Miscellaneous**
 - plug loads
 - computer equipment can be significant

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Conducting an Audit

- **Energy Audit Tools**
 - Tape Measure
 - Lightmeter
 - Wattmeter/Voltmeter/Ampmeter
 - Combustion Analyzer
 - Thermometer
 - Airflow Measuring Devices
 - Safety Equipment

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Questions?

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Energy Assessment and Audit Methodology for Refurbishing Buildings

Presenter: Dr. Andrey Strongin. Central Research Institute for Industrial Buildings (Russia).

Dr. Eugene Shilkrot, Dr. Andrey Strongin.
Central Research Institute for Industrial Buildings
Moscow, Russia.

**Energy Audit of Residential and
Industrial Buildings in Russia**

STAGES OF ENERGY AUDIT

- 1. Studying of streams of energy in a building.
- 2. Development of recommendations on an effective utilization of energy

LEVELS OF ENERGY AUDIT

- The analysis of the design decision.
- The analysis of the project and measurement of some parameters.
- Tool inspection.

POTENTIAL OF ECONOMY OF ENERGY

- It is established on the basis of comparison of actual specific parameters of a power consumption with normative or with the best in domestic and world practice.
- The potential is estimated in natural parameters: economy – Kw-hr, KJ, ton fuel, and so forth, and economic in view of investments and operational expenses – economy – RUBLES, payback time–years, and so forth.

ELEMENTS OF ENERGY AUDIT

Elements	Level 1	Level 2	Level 3
Power consumption, specific characteristics		X	X
Estimation of engineering systems and building envelope		X	
The design documentation	X	X	X
Testing of the inhabitants and personal		X	X
Measurements, a minimum level		X	
The measurements, a required level			X
Balance of heat		X	X
Potential of economy	X	X	X
Primary investment offers	X	X	
The proved investment offers			X

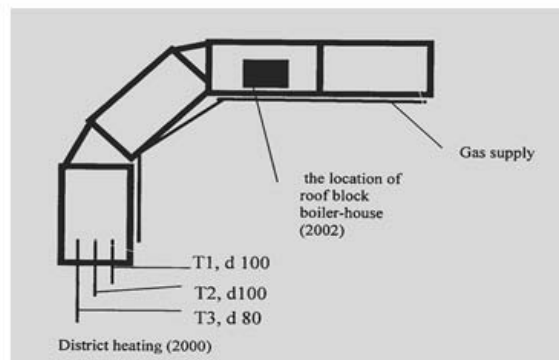
EXAMPLES OF ENERGY AUDIT

- 1. THE RESIDENTIAL BUILDING
- The characteristic of a building
- The general area - 10040 m²
- Number of floors - 10
- Number of apartments - 156
- Year of construction - 1995
- Level of energy audit – 3 (tool inspection)

THE RESIDENTIAL BUILDING



THE RESIDENTIAL BUILDING



TASK OF ENERGY AUDIT

- Estimation of quality of a heat supply and parameters energy consumption a multi-storey apartment house at the centralized and independent heat supply.
- **Stage 1.** 2000. District heat supply from central heating station.
- **Stage 2.** 2002-2003. Heat supply from an independent source – roof- boiler-house.

ELEMENTS OF ENERGY AUDIT

- The control of consumption by a building of all power resources (heating, cold and hot water, the electric power, gas for household needs)
- Measurements of parameters of a microclimate in representative apartments (temperature and humidity of air, temperature of building envelope, the charge of ventilating air)
- The control of parameters of an external climate (temperature, speed and a direction of a wind)
- The statistical analysis of subjective parameters on the basis of questioning tenants
- The control of parameters of work of engineering systems

UNITS

- DD - degree – day
- °C – degree Celsius (Centigrade °C)
- ton fuel – ton of Conventional fuel
- W - watt
- KW – kilowatt, $KW = 10^3W$
- MW- megawatt $MW = 10^6W$
- J - Joule
- GJ - gigajoule $GJ = 10^9 J$
- Sec- second
- hr - hour
- m - metr
- L - litre

CONSUMPTION OF HEAT ENERGY ON HEATING

1.	The general area	m ²	10040	10040
2.	Average external temperature for the period of measurements	° C	-4,4	-10,8
3.	The charge of heat on heating	GJ	855,6	902
4.	Hourly average parameters of the charge of heat	MW	0,353	0,41
5.	The same on 1 m ² of the heated area	W/m ²	35,13	44,08
6.	The charge of heat in relation to degree-day on 1 m ² of the heated area	KJ/DD.m ²	102,7	100,6
7.	The charge of heat on heating on settlement temperature of external air-28 ° C and temperature of a premise +21 ° C	MW	0,68	0,63
8.	The same on 1 m ² of the heated area	W/m ²	67,7	62,8

CONSUMPTION OF HEAT ENERGY ON HOT WATER SUPPLY (HWS)

№ №	Parameters	Unit	Results	
			1 stage	2 stage
1.	The charge of heat on HWS	GJ	376,74	290
2.	The hourly average charge of heat on HWS	MW	0,156	0,12
3.	The hourly average charge of heat on HWS on 1 m ² of the area of a house	W/m ²	15,51	11,94
4.	The charge of heat on HWS, related to degree-day on 1 m ² of the area of a house	KJ/DD.m ²	45,29	32,35

CONSUMPTION OF HEAT ENERGY ON HOT WATER SUPPLY (HWS)

№№	Parameters	Unit	Results	
			1 stage	2 stage
1.	The charge of heat on HWS	GJ	376,74	290
2.	The hourly average charge of heat on HWS	MW	0,156	0,12
3.	The hourly average charge of heat on HWS on 1 m ² of the area of a house	W/m ²	15,51	11,94
4.	The charge of heat on HWS, related to degree-day on 1 m ² of the area of a house	KJ/DD.m ²	45,29	32,35

CONSUMPTION OF COLD AND HOT WATER

№№	Parameters	Unit	Results	
			1 stage	2 stage
1.	The charge of water:			
	cold	m ³	1931	2292
	hot		1895	1817
2.	The hourly average charge of water:			
	cold	10 ³ m ³ / sec	0,798	0,947
	hot		0,783	0,751
3.	The hourly average charge of water on 1 m ² of the area of a house:			
	cold	10 ³ m ³ / sec. m ²	0,08	0,101
	hot		0,078	0,075
4.	The hourly average charge of water on 1 inhabitant:			
	cold	10 ³ m ³ / sec	1,54	1,82
	hot		1,5	1,44
5.	The daily average charge of water on 1 inhabitant:	L/day		
	cold		133	157
	hot		130	125

CONSUMPTION OF THE ELECTRIC POWER

№№	Parameters	Unit	Results	
			1 stage	2 stage
1.	The charge of the electric power	GJ(KW-hr)	34,45 (9569)	32,06 (8906)
2.	The hourly average charge of the electric power	KW	14,24	13,3
3.	The hourly average charge of the electric power on 1 m ² of the area of a house	W/m ²	1,42	1,3
4.	The charge of the electric power on 1 m ² of the area of the house, related by degree-day	KJ/DD.m ²	4,14	3,6

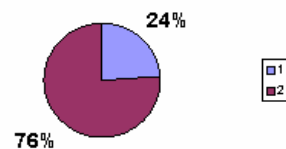
CONSUMPTION OF GAS ON HOUSEHOLD NEEDS

№ №	Parameters	Unit	Results	
			1 stage	2stage
1.	The charge of gas for the period of measurements	m ³	1999	1984
2.	The hourly average charge of gas	10 ³ m ³ / sec	0,86	0,82
3.	The hourly average charge of gas on 1 m ² of the area of a house	10 ⁶ m ³ / sec. m ²	86	81,7
4.	The hourly average charge of gas on 1 apartment	10 ⁶ m ³ / sec	5,53	5,3
5.	The hourly average charge of gas on 1 inhabitant	10 ⁶ m ³ / sec	1,64	1,58
6.	The charge of gas on 1 m ² of the area of the house, related by degree-day	10 ⁶ m ³ / DD.m ²	0,32	0,22
7.	Hourly average allocation of thermal energy at action of gas cookers on 1 m ² of the area of a house	W/m ²	2,76	2,74
8.	Hourly average allocation of thermal energy at action of gas cookers on 1 m ² of the area of the house, related by degree-day	10 ³ W/m ² .DD	3,33	3,07

PARAMETERS OF A MICROCLIMATE IN APARTMENTS

Parameter	Apartment 6		Apartment 32		Apartment 131	
	2002	2003	2002	2003	2002	2003
Temperature of air,						
minimal	13,6	18	9,5	20,5	14	16
maximal	24,2	22,5	25,6	24	24,8	20
average for the period of measurements, °C	20,2	21	19,1	22,5	19,8	19,5
Relative humidity, %						
minimal	44	28	52	34	60	28
maximal	66	45	68	55	78	43
average	52	38	50	42	70	36
Average temperature of external air °C	-4,4	-10,8	-4,4	-10,8	-4,4	-10,8

RATIO OF POWER CONSUMPTIONS IN APARTMENT HOUSES ON NATURAL VENTILATION, HEATING AND HOT WATER SUPPLY (%)



1 - hot water supply
2 - heating and natural ventilation

THERMAL BALANCE OF APARTMENTS 2000 - 2003.



1 – heated towel rails 2 – gas cookers 3 – electrodevices 4 – people 5 – heating

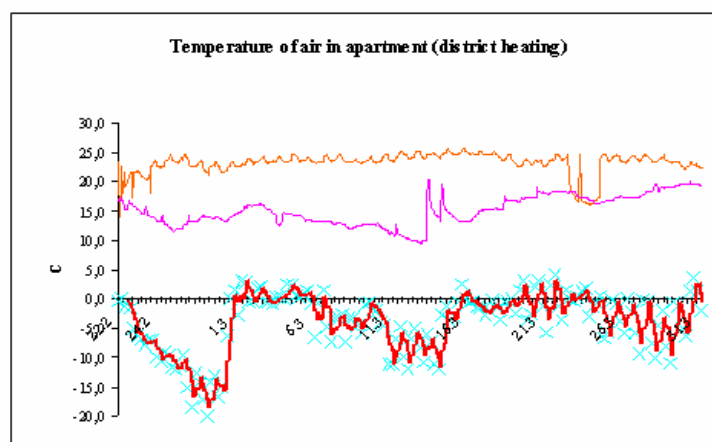
THE BASIC COMPARATIVE HEAT POWER PARAMETERS OF WORK OF THE CENTRALIZED AND INDEPENDENT SOURCES OF A HEAT SUPPLY

№№	Parameters	Unit of measurements	Values	
			1 stage	2 stage
1.	The charge of heat on heating and ventilation	KJ/DD.m ²	102,7	100,6
2.	The charge of heat on hot water supply	KJ/DD.m ²	45,2	32,35
3.	The charge of the electric power	KJ/DD.m ²	4,14	3,6
4.	The charge of gas on household needs	10 ³ m ³ / DD.m ²	0,32	0,22

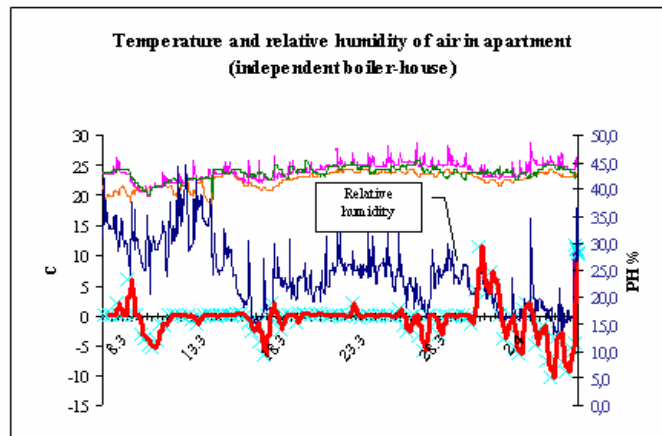
ESTIMATION OF EFFICIENCY OF USE OF PRIMARY FUEL ON A HEAT SUPPLY

№ №	Parameters	Unit of measurements	Values	
			Centralized	Independent
1.	The relative charge of heat on a heat supply	KJ/DD.m ²	147,9	132,95
2.	Unproductive losses of heat	%	34	1
2.1.	In thermal networks	%	16	0,5
2.2.	In central distributive station	%	3	0,5
2.3.	In thermal power station	%	15	
3.	The charge of fuel on 1 unit of thermal energy on input in the house	10 ⁻³ Ton fuel / GJ	55,88	37,96
4.	The charge of the electric power on 1 unit of thermal energy on input in the house	KW-hr/GJ	54	3,36

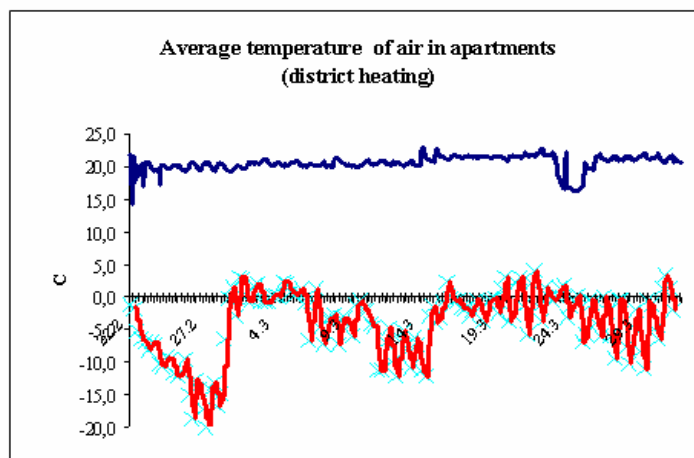
EXPERIMENTAL DATES



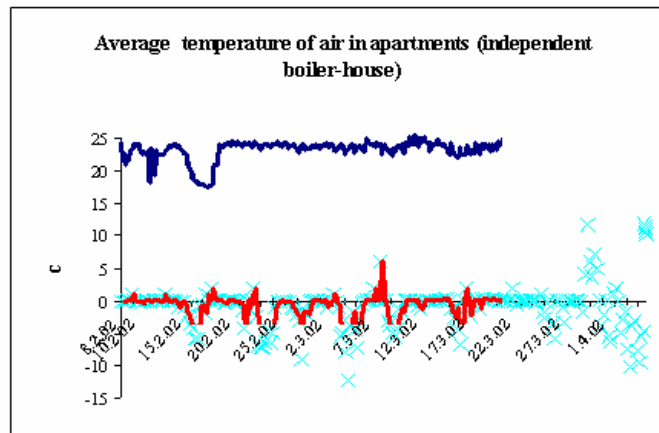
EXPERIMENTAL DATA



EXPERIMENTAL DATA



EXPERIMENTAL DATA



THE BASIC CONCLUSIONS

- Air - thermal comfort of apartments for the account of more full conformity of modes heat consumption and heat production, elimination "under heating" and "super heating" has increased. Inhabitants have increased air exchange by 30-50 % due to regular airing. Relative humidity of air in apartments has decreased on 10-15 %.
- In thermal balance of apartments the share of thermal emissions from gas cookers and electro heaters has decreased.
- Specific parameters of heat consumption on heating and hot water supply practically have not changed.
- Unproductive losses of heat and the electric power in systems of a heat supply have essentially decreased, that allows to save about 30 % of primary fuel.
- The given testing confirm increase of comfort of residing. Temperature of air in the winter in apartments from 18 up to 25 ° C in 2000 37 % of tenants, and in 2003 – have noted 74,2 %. At the same time, temperature 15-17 ° C in 2000 55,9 % of inhabitants, and in 2003 – only marked 11,8 %. Direct heating of air by products of combustion of a household gas cooker has decreased on 13 %. The number of complaints in administration has decreased.

2. THE INDUSTRIAL BUILDING

- The characteristic of a building
- Purpose - mechanical-repair workshop
- The general area - 648 m²
- Building volume - 3664,4 m³
- Year of construction - 1989
- Level of energy audit – 1 (the analysis of the design decision)
- Task of energy audit
- Reduction of thermal energy consumption on heating and ventilation of a building, preparation and an estimation of investment offers.

THE DESIGN DATA

- Settlement temperature of outside air - -28 °C
- Settlement temperature of inside air - 17 °C
- Average temperature of outside air for the heating period - -3,1 °C
- Duration of the heating period – 216 days
- Number of supply systems – 4
- The charge of supply air – 37400 m³ / hr
- Rate of air exchange – 10,2 1/hr
- Number of local exhaust – 7
- The charge of air, in local exhaust – 13060 m³ / hr
- Number of exhaust systems general mechanical ventilation – 3
- The charge of air, exhaust mechanical general ventilation – 10650 m³ / hr
- The charge of air, exhaust systems of natural ventilation – 13690 m³ / hr
- Thermal capacity of system of heating – 90,7 kW
- Thermal capacity of system of ventilation – 515 kW
- The established capacity of electric motors of ventilation systems – 20,6 kW
- Thermal envelope:
- - walls – brick, thickness of 0,38 m, $R_w = 0,76 \text{ m}^2 \cdot ^\circ \text{C/W}$
- - a covering – steel-concrete plates, a heater – foam concrete, $R_{cov} = 0,985 \text{ m}^2 \cdot ^\circ \text{C/W}$

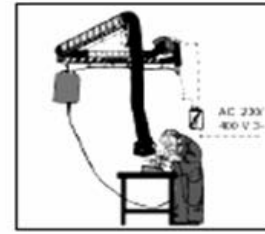
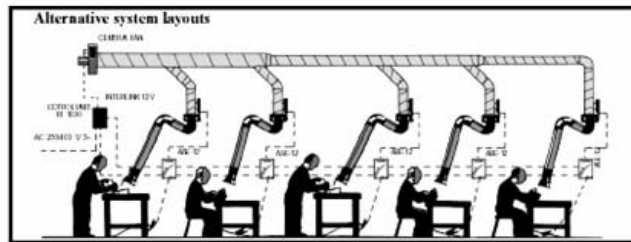
ACTIONS ON REDUCTION OF THE CHARGE OF THERMAL ENERGY

- Warming of building envelope (walls, a covering) by mineral plates. A new level of heat-shielding $R = 1,93 \text{ m}^2 \cdot ^\circ \text{C/W}$

ACTIONS ON REDUCTION OF THE CHARGE OF THERMAL ENERGY

- Reduction of air exchange due to application more effective local exhaust.
- - the maximal approach to a place of allocation of pollutants,
- - flexibility,
- - application of filters about a degree of clearing up to 98 %,
- - return of cleared air to a premise.
- Number of reconstructed systems local exhaust – 4.
- The general reduction in the charge of exhaust air – $9700 \text{ m}^3 / \text{hr}$

EFFICIENT FUMES EXTRACTORS



ESTIMATION OF EFFICIENCY OF THE OFFERED ENERGY SAVING ACTIONS

Condition of object	The mid-annual charge of heat on heating, KW-hr	The mid-annual charge of heat on ventilation, KW-hr	The sum of mid-annual charges of heat, KW-hr	Settlement economy,
Before reconstruction	286330	388910	675240	-
Reconstruction of envelope	117000	388910	505910	25
Reconstruction of ventilation systems	286330	171000	457330	32,2
General reconstruction (envelope and ventilation)	117000	171000	288000	57,2

ESTIMATION OF PAYBACK TIME OF ENERGY SAVING ACTIONS

- $T = K / (E_1 - E_2)$
- K - investments in energy saving actions, RUB
- E_1, E_2 – annual cost of thermal energy before and after performance of actions, RUB/year
- Payback time of reconstruction building envelope
- $T = 542,5 \cdot 1000 / (200 - 53,4) 1000 = 3,7$ years
- Payback time of reconstruction of ventilation systems
- $T = 166,6 \cdot 1000 / (267,2 - 112,4) 1000 = 1,08$ years

Process Energy and Pollution Reduction at DOD Facilities

Presenter: Dr. Mike Lin, ERDC-CERL

Process Energy and Pollution Reduction (PEPR) at DoD Industrial Facilities



Dr. Mike Lin

1-800-USACERL (X7358)

Mike.C.Lin@erdc.usace.army.mil



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Background

- Industry accounts for 36% of US energy (\$100B/yr)
- DoD spends \$3B/yr, \$280M/yr at industrial facilities
- Process energy is reported on a voluntary basis
- AMC installations consume about 13 TBtu/yr for industrial processes, costing \$72M/yr
- Studies show that 20% reduction is possible
- However, it has not been very effective in DoD due to the lack of an incentive structure
- Most of the industrial facilities are GOCO

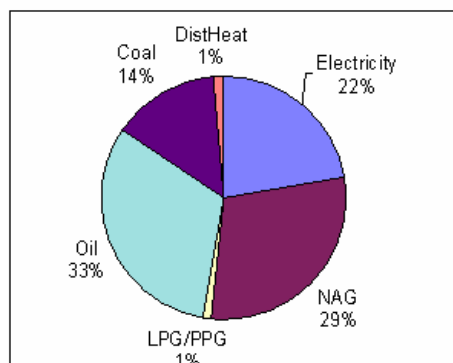


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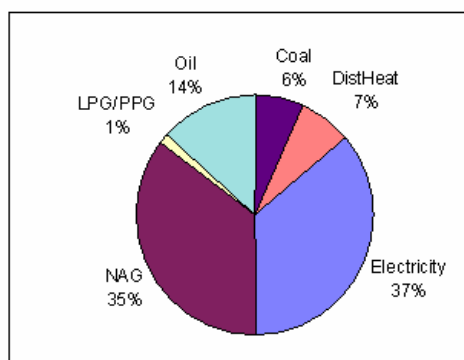
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Army Reported Energy Usage

FY 85 – 132 TBtu



FY02 – 82 TBtu



- **AMC installations consume about 13 TBtu/yr for industrial processes, costing \$72M/yr**



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DoD Policy Requirements

- **ENERGY:** Executive Order 13123
 - Increase Industrial Efficiency 20% (1990 to 2005)
 - Increase Industrial Efficiency 25% (1990 to 2010)
 - Implement water conservation measures
- **COMPLIANCE:** Executive Order 12856
 - Promote Renewable Energy Technology
 - 50% Reduction in Toxic Pollutant Releases
- **POLLUTION PREVENTION:** Executive Order 12873
 - Incorporate Waste Prevention and Recycling
 - Use 'Environmental Preferable' Products/Services
 - Procurement Guides to Incorporate EPA Guidance



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What Is CERL Doing for the Army in Process Energy Optimization?

Identify and Demonstrate New opportunities for Army Process Energy and Pollution Reduction (PEPR) Through:

- New Technologies
- Improved Systems and Operational Modifications

Emphasis is placed on implementing changes that can be applied to numerous military installations with significant industrial activities



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Our Customers



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Typical DoD Processes

- Metal working: cutting, welding, machining, heat treating
- Spray painting & de-painting
- Electroplating
- Load, assemble & pack (LAP)
- Explosives/propellants production
- Steam systems
- Compressed air systems
- Motor/engine testing & repair



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Major Cost Issues

- Capacity Utilization: Bottlenecks
- Material Utilization: Off-Spec, Scrap, Rework
- Labor: Productivity, Planning/Scheduling
- Energy: Steam, Electricity, Compressed Air
- Waste: Air, Water, Solid, Hazardous
- Equipment: Outdated or State-of-the-Art



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Process Optimization

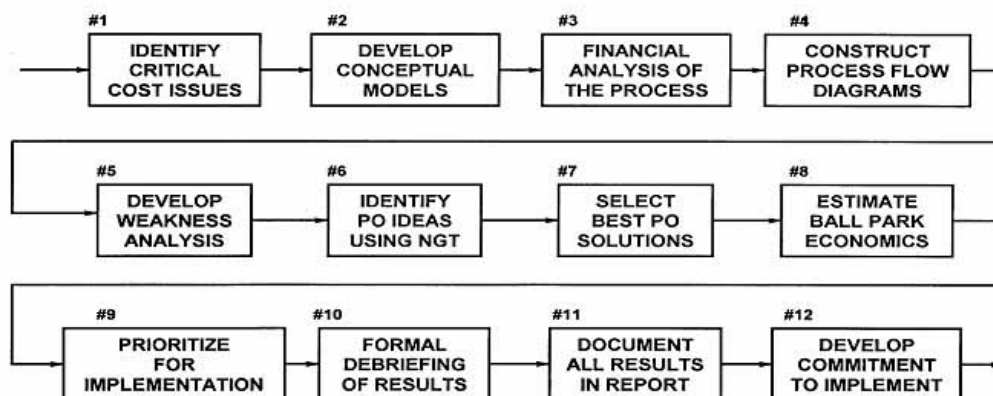
- Extends conventional energy & environmental auditing to production/maintenance processes
- Uses a 12-step methodology and includes all major cost issues
- Financially audits the industrial process
- Links process changes to the “Bottom-line”



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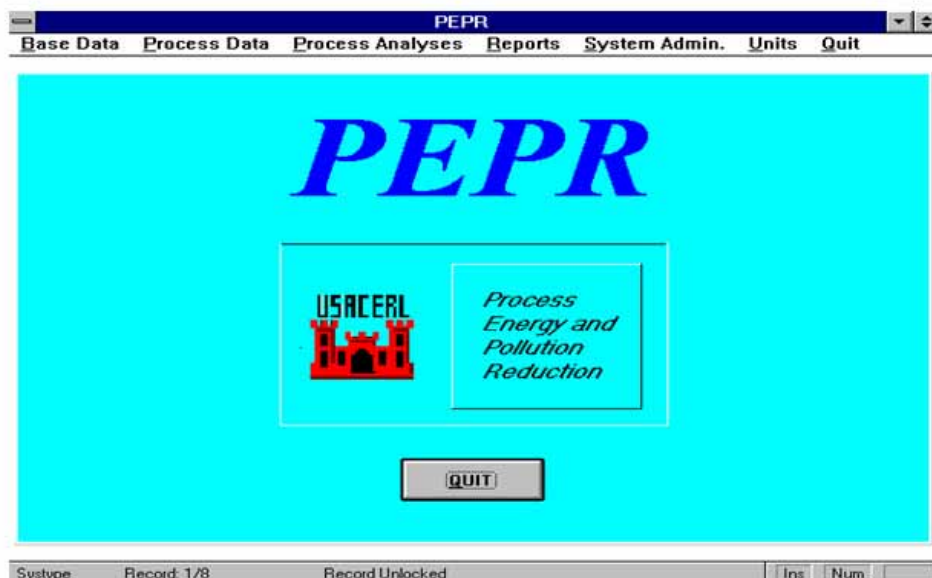
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FIGURE 1: TWELVE STEPS OF THE PO METHODOLOGY



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Process Energy & Pollution Reduction (PEPR) an Analysis Model

- Builds process database
- Constructs process flow diagram
- Estimates process energy & emissions
- Suggests innovation techniques
- Calculates SIR and PB period
- Provides technical reference & unit conversion
- Screens DoD industrial operations
- Supports technology transfer



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Case Examples Contained in PEPR

- Heat Treating
- Spray Painting
- Electroplating
- A Load, Assemble and Pack Line (LAP)
- Explosives Production
- Steam/Hot Water Distribution System
- Compressed Air Distribution System



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ERDC-CERL Support to Industrial Energy

**Research for
decision
support tools**

HEATER/Heatmap:

- PICA
- ARL-Adelphi
- and troop installations

*Estimate life cycle cost of
repair, replacement, and
upgrade options.*



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*Minimizes greenhouse
pollutants*

PEPR audits:

- PBA
- WVA
- ANAD
- TYAD

*Average 20% + increase in
process energy efficiency &
reduced O&M costs*

**Technology
demonstration
projects**

**Low NOx Boiler
Demo's:**

- WVA
- and 3 troop
installations

*Average total energy
savings per plant =
~44%*

NGEDAC Demo's:

- PICA
- WVA
- SIAD

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Industrial Energy Optimization

<u>Action</u>	<u>Where</u>	<u>When</u>
PO Workshop & Audits	Pine Bluff Arsenal, AR	June 94 & Aug 96
PO Audit	Anniston Army Depot, AL	July 1995
PEPR Software	CERL	May 1996
PO Workshop & Audits	Watervliet Arsenal, NY	Feb 1999
PO Guide	CERL	May 1999
PEPR Enhancement	CERL	June 2000
PO Workshop & Audit	Tobyhanna Army Depot, PA	June 2002
PO Audit	Ft. Leonard Wood, MO	April 2003
PO Audit	Ft. Carson, CO	May 2003



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How is Process Optimization Assessment (POA) Conducted?

- The POA Follows a Proven, Systematic, Multi-Step Methodology
- High level analysis that targets only big \$\$ issues
- It's Fast, we only need access to identified resources for 2-5 days
- A Team Effort by On-Site Process Experts, Guided and Documented by Process Analysis Experts (Mr. Walt Smith of ETSI Inc. provided consulting support)
- Quantifies the value of the POA solutions using Simple Payback
- After management approval continue with Level II analysis on top improvement ideas for funding and implementation



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Accomplishments (Past 2 Years)

- Process Energy Optimization Level I Review at Tobyhanna Army Depot (June 2002)
- Compressed Air System Survey & System Management Software Tool (11 Army Industrial Bases)
- NGEDAC Demo (WVA, PICA and SIAD)
- Low Emission Boiler Demo (WVA, Ft. Dix, Campbell, Stewart)
- AMC Support to ESPC's (PICA HeatMap)
- White Paper on Industrial Energy Optimization
- Process Optimization Assessment at
 - Ft. Leonard Wood, MO (April 2003)
 - Ft. Carson, CO (May 2003)



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Process Optimization Assessment at Ft. Leonard Wood and Ft. Carson

The 5-Day Audit Covered the Following Industrial Processes:

- (1) Central heating plants
- (2) Laundry
- (3) Painting and Media blasting
- (4) Engine overhaul and Vehicle repair

We Identified Opportunities, for each Process, to:

- (1) Improve Performance
- (2) Increase Efficiency and to Reduce Energy and Emissions including Air, Water and Solid Waste.

We Developed, for each Process:

- (1) Preliminary Capital Investments
- (2) Potential Cost Savings from Process Optimization and Improvement



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Process Optimization Assessment Results

Army Base	Fort Leonard Wood	Fort Carson
# of Post Wide ECM	5	10
# of Heating Plant ECM	11	9
# of Laundry ECM	4	N/A
# of Maintenance Complex ECM	6	10
Total # of ECMs	26	29
Savings	\$1,963,275	\$2,117,250
Investment	\$1,929,300	\$1,250,300
Simple Payback	1 yr.	0.6 yr



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NGEDAC Demonstrations




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NGEDAC Application Web Site

<http://www.aircompressor.org/>



The screenshot shows the NGEDAC Application Web Site. The header features the title "Natural Gas Engine-Driven AIR COMPRESSORS" in large, bold letters. To the right of the title are logos for the "Industrial Center" and the "U.S. Army Corps of Engineers Engineer Research and Development Center Construction Engineering Research Laboratory". Below the title, there is a navigation menu on the left with links: Benefits, Technology, Economics, Buyers' Guide, Case Studies, Consortium, Industrial Center, FAQ, Other Resources, and Contact. Below these links are links for Sitemap and Home. The main content area is titled "Something to consider..." and contains a paragraph explaining that compressed air is essential in most manufacturing plants, and the cost to produce it is much higher than most people realize. It states that it is not unusual for 30 percent of a plant's electric utility costs to go toward the production of compressed air. Even more surprising is that the annual electricity cost to operate an electric air compressor can equal or exceed the first cost of the unit. To the right of the text is a collage of images showing various industrial air compressor units and facilities. At the bottom of the main content area, a paragraph states: "Natural gas engine-driven air compressors greatly reduce power demand and energy consumption costs."



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Low NOx Boiler Demo

Sites/Status

- **WVA, NY** – 70K pph Todd/Donlee
 - NG/oil, upgrade FY03
- **Ft. Dix, NJ** – 22K pph Johnson/Donlee
 - NG only, operating since 31 Dec 02
- **Ft. Campbell, KY** – 34K pph Donlee
 - NG/oil, upgrade FY03
- **Ft. Stewart, GA** – 50K pph Todd/English
 - NG/oil, start-up in progress



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ERDC/CERL Technical Reports

- "Energy Conservation and Air Toxic Compliance Plan for DoD Industrial Facilities"
- "Level I Process Energy Review and PEPR Workshop at Pine Bluff Arsenal"
- "Level II Audit of White Phosphorus Dry-Fill Process at Pine Bluff Arsenal"
- "Level II Audit of Smoke Grenade Manufacturing Process at Pine Bluff Arsenal"
- "Development of Process Energy and Pollution Reduction Analysis Tool"
- "Identification of PEPR Opportunities at DoD Industrial Facilities"
- "Process Optimization Guide for Military Manufacturing and Maintenance Facilities"**
- "PEPR Level I Review at the Watervliet Arsenal"
- "Applications Guide for Compressed Air Systems"
- "Compressed Air System Survey at Army Industrial Facilities"
- "Demonstration of Natural Gas Engine Driven Air Compressor at Army Industrial Facilities"
- "Process Energy Optimization Level I Review, Tobyhanna Army Depot, PA"
- "Process Optimization Assessment, Fort Leonard Wood, MO and Fort Carson, CO"



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<http://www.cecer.army.mil>

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Summary and Conclusions

- **Energy Can Be Used to Improve Process Performance, Directly Contributing to the Business Unit's Bottom Line.**
- **The POA Approach is Best Characterized by the Motto: "Change... Focus... Speed"**
- **Energy is an Important Solution Tool. However, Rethinking and Optimizing All Inputs to the Process Systems are the Total Answer.**
- **The 2-5 Day POA Provides the Change, Focus and Speed to Achieve Significantly Faster and Far Greater Profitability than Other Traditional Energy Audit Approaches.**

Thank

You !



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Methodology for Cost Effective Assessment of Heat Recovery Potentials

Presenter: Dr. Christoph Weber. University of Stuttgart (Germany).

University of Stuttgart, Germany
Institute of Energy Economics and the Rational Use of Energy

IER

Methodology for cost effective assessment of heat recovery potentials

**Industry Workshop
Chicago, October 7 - 8, 2003**

**C. Weber, B. Leven, C. Schaefer
IER, University of Stuttgart, Germany**

Assessment of a Waste Heat Source - Conventional Approach

Identification of a waste heat source

Collection of information

Site survey

Measurements (e. g. load curve)

Calculations

Technical Concept (i. e. Feasibility)

Profitability analysis

Decision about realization

- **Disadvantage:**
Very time consuming

- Assessment of several combinations of the waste heat source and possible heat sinks (consumers or networks)
- Collection of information and analysis for every combination

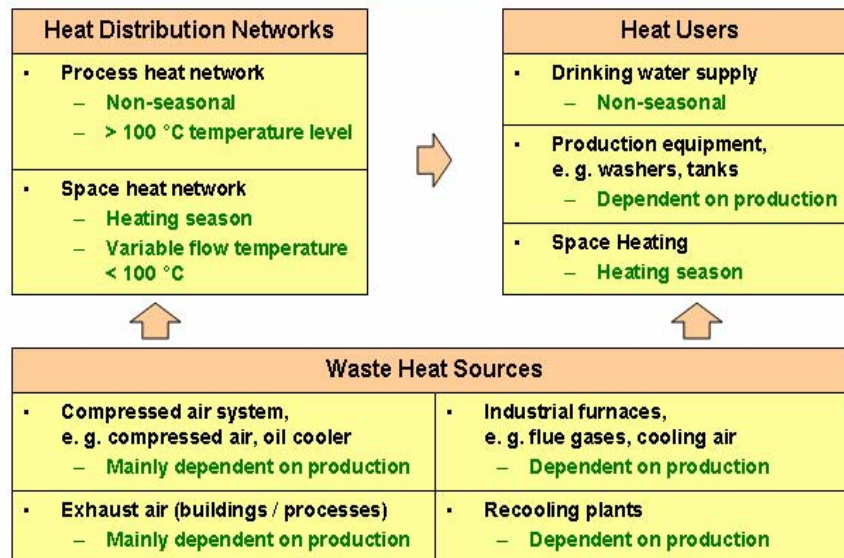


- **Standardized procedure for the approximate estimation of economical and technical aspects by applying a software tool**

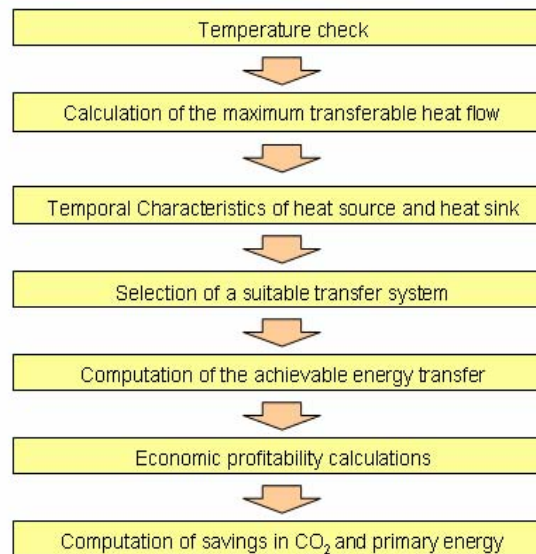
Requirement for the new methodology

- **Integration of typical heat sinks and waste heat sources of at a given site**
- **Information collection by applying a data entry form**
- **No measurements and no application of load curves**
- **Estimation of economical and technical aspects, no detailed planning**
 - absolute energy saving, demand for auxiliary energy (e. g. for pumps)
 - capital cost, payback period, internal rate of return
 - reduction of CO₂-emissions and demand for primary energy
 - sensitivity analysis concerning energy prices
- **Calculations with specific prices, no call for tenders (e. g. prices of HVAC equipment, heat exchangers etc.)**
- **Application through a software tool designed for users with energy-related skills**

Classification of Heat sources and heat sinks



Calculation methodology



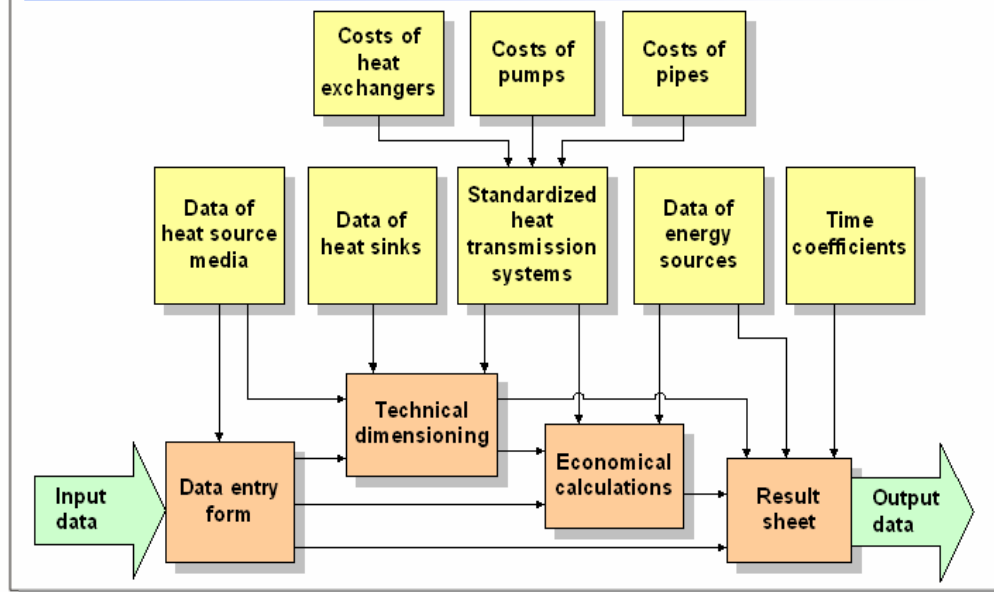
Computation of the achievable energy transfer

- **Use of multiplicative factors to describe**
 - Seasonal impacts,
 - Production dependent impacts
 - Load factor during the production time
- **These factors (minimum of source and sink) are used to determine effective annual operation hours for heat transfer**
- **Operation hours are multiplied with average heat flow during operation**
- **Example:**
 - **heat source:**
 - not subject to seasonal influences
 - operating in a two-shift production line
 - about 10 % of the production time
 - **heat sink**
 - only available during the heating period
 - independent of the production.
 - **number of operating hours for the connection of source and sink:**
 - Operating Hours [h/a] = 8760 h/a * „heating period“ * „2-shift production“ * 0.1

Design of the Software Tool

- **Standardized data entry form**
 - also for print out and on-site information collection
 - Input of the essential data
- **Coefficients for the seasonal characteristics and operating times of heat sources and heat sinks**
 - Seasonal, production and plant coefficient
- **Definition of standardized heat exchange systems**
 - Liquid and gaseous heat source media
 - Standardized heat sinks of the site
- **Integrated characteristics of media (e. g. density, specific heat capacity) and specific prices or price functions**
 - Possibility to edit data by the user
- **Combination of any heat source with all standardized heat sinks of the site**
 - Automatic calculation of the essential data as basis for decisions

Structure of the Software Tool



Data Entry Form - Input Data (Selection)

Waste heat source

- **Medium**
 - Flue gas from gas firing
 - Flue gas from oil firing
 - Flue gas from coal firing
 - Exhaust air
 - Compressed air
 - Oil
 - Water
- **Flow rate, inlet temperature, minimum outlet temperature**
- **Time characteristic**
 - Seasonal (yes or no)
 - Production (shifts per day)
 - Plant

Heat sinks

- **Standardized**
 - Air supply for buildings
 - Drinking water supply
 - Washers
 - Process heat network
 - Space heat network
- **Time characteristic**
 - Seasonal
 - Production
- **Energy source**
 - Natural gas
 - Hot water
 - Electricity
- **Distance to waste heat source**

Output Data (Selection) - Output for each suitable heat sink

- **Technical**
 - Transferable heat flow [MW]
 - Useful operating time [h/a]
 - Transferable heat [MWh/a]
 - Demand of auxiliary energy [MWh/a]
- **Economical**
 - Annual cost savings [€/a]
 - Capital cost for heat exchangers, pipes, pumps etc. [€]
 - Payback period [a]
 - Internal rate of return [%]
 - Sensitivity analysis concerning energy prices
- **Ecological**
 - Reduction of CO₂-emissions [tons/a]
 - Reduction of primary energy demand [MJ/a]

Conclusion and Outlook

- **Possibilities and limitations**
 - First estimation of economical and technical aspects for standardized heat sinks
 - Reduced requirements in staff and financial resources for the collection of data and the calculations
 - Support for pre-selection, no detailed planning
 - Data referring to the individual site
- **Outlook**
 - Software tool is currently applied on case studies in the automotive industry
 - Results of the case studies provide information for improvements (e. g. specific prices)
 - Transformation to conditions of other sites or branches is possible